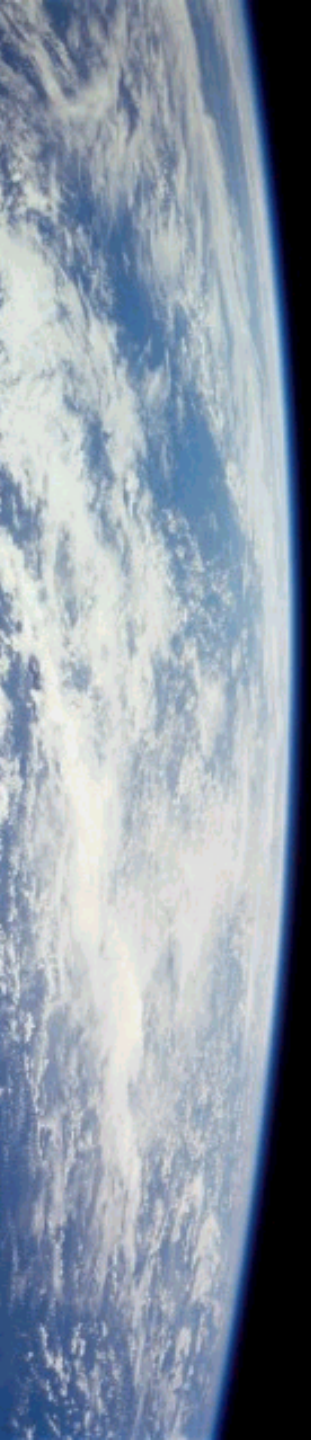


Track reconstruction in AMS: RICH standalone and RICH+TOF

Rui Pereira, Luísa Arruda, Fernando Barão

(LIP - Lisbon)

AMS analysis meeting, Madrid, 24-25 May 2007

Motivation

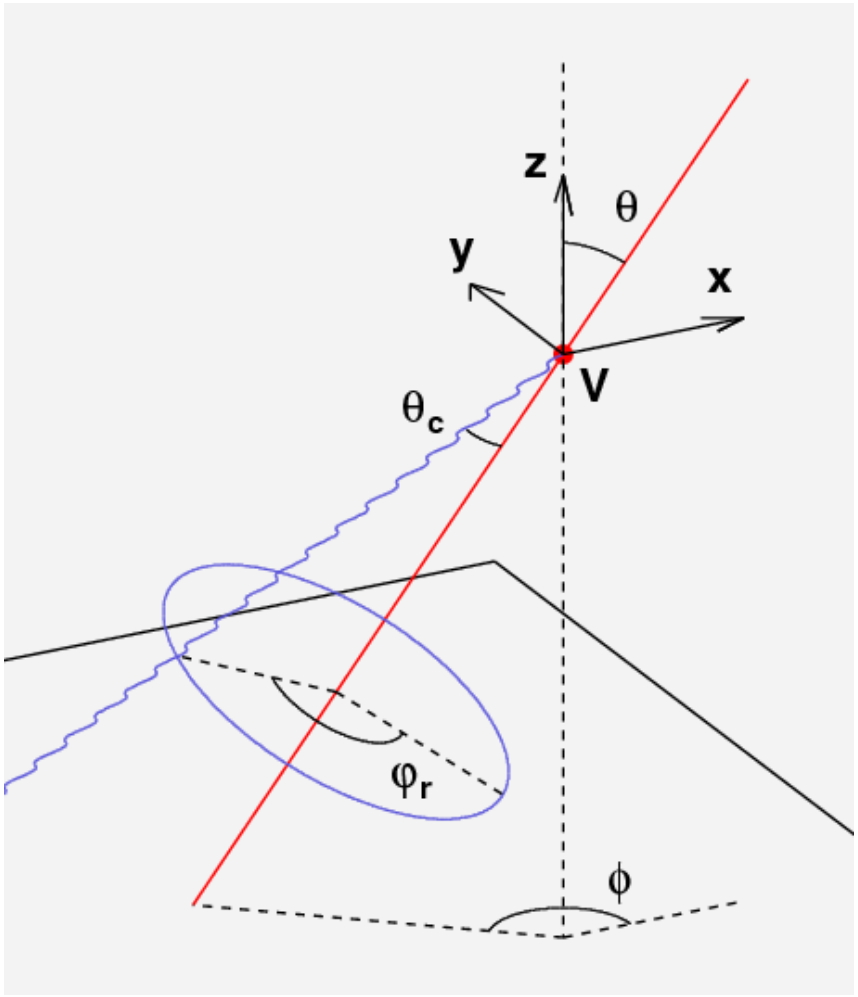
- Standard track reconstruction in AMS is based on Silicon Tracker data

- It is important to have an alternative method for track reconstruction in AMS without Tracker data, e. g.:
  - if the Tracker system is absent
  - if there is no magnetic field

- Data useful for track reconstruction include
  - TOF clusters
  - RICH signal (ring hits, particle crossing signal)

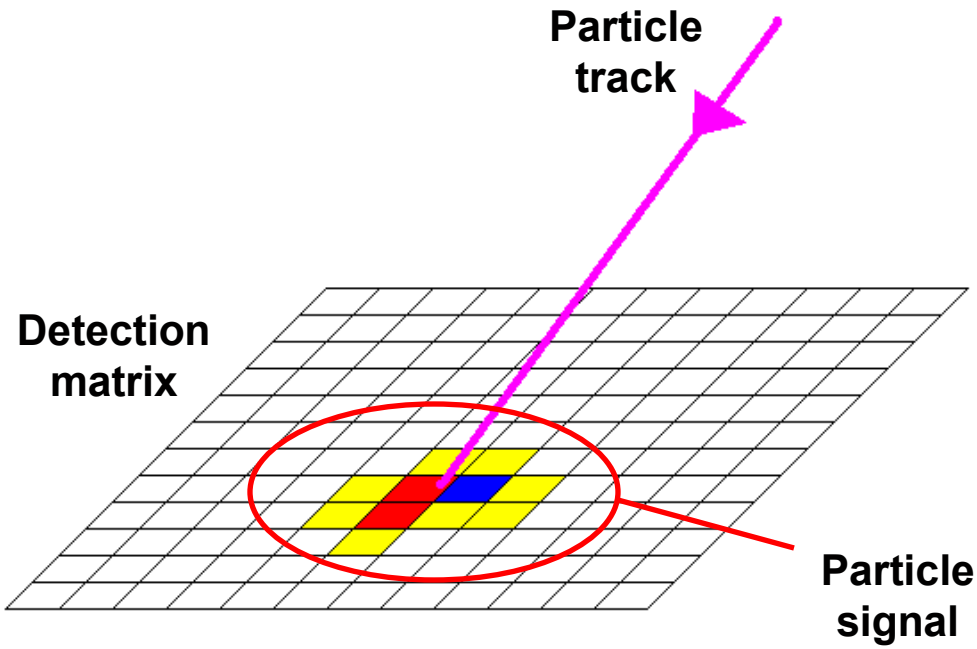
RICH standalone reconstruction

- Goal: event reconstruction using only data from the RICH detector
- No Tracker or TOF data used
- 5 parameters for reconstruction:
  - matrix impact point (x_{matrix}, y_{matrix}), θ, ϕ, θ_c
- Likelihood function used (similar to 1-parameter reconstruction)
- Sample used: proton events in the AMS-02 full simulation with $p > 10$ GeV/c ($\beta \approx 1$)



RICH standalone reconstruction

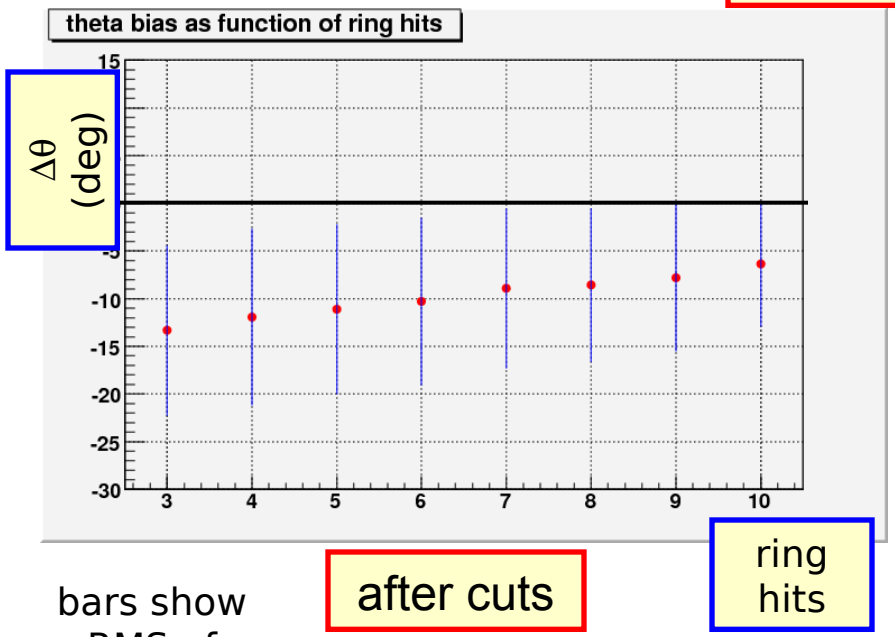
- PMT matrix crossing point identified by strong signal in matrix (much stronger than ring hits)
- Quality cuts for hint:
  - Quotient between strongest and average PMT signal must be higher than 3 and lower than 10
  - Strongest PMT signal must be higher than 6 p.e.

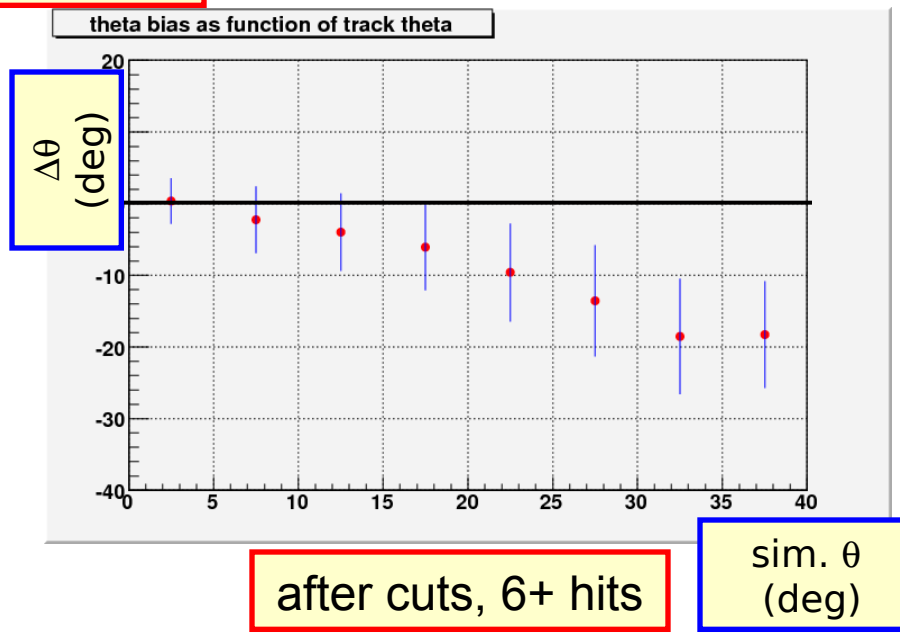


Standalone reconstruction quality

- Main problem: strong bias in θ reconstruction
  - Bias increases with θ, spread also increases
  - Reconstructed θ is, on average, about half of simulated angle
  - Bias is smaller for events with higher number of hits
    - Still, $\Delta\theta \sim 7°$ for events with 10 or more hits
  - Note: corrections on effective depth of light guide signal (average value of 1.8 cm used here) were tested, with no significant changes on reconstruction quality

ALL EVENTS

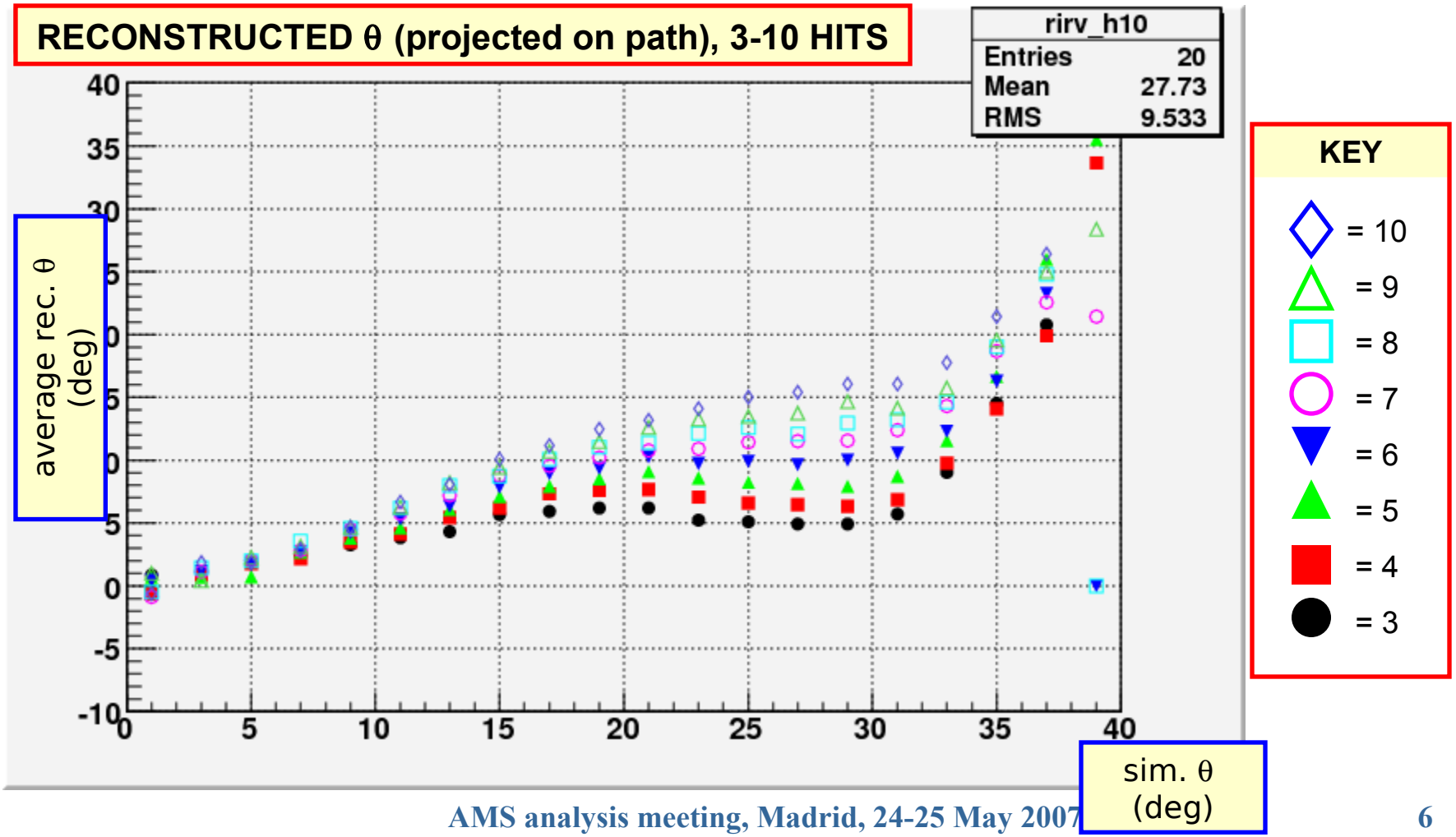




bars show RMS of distributions

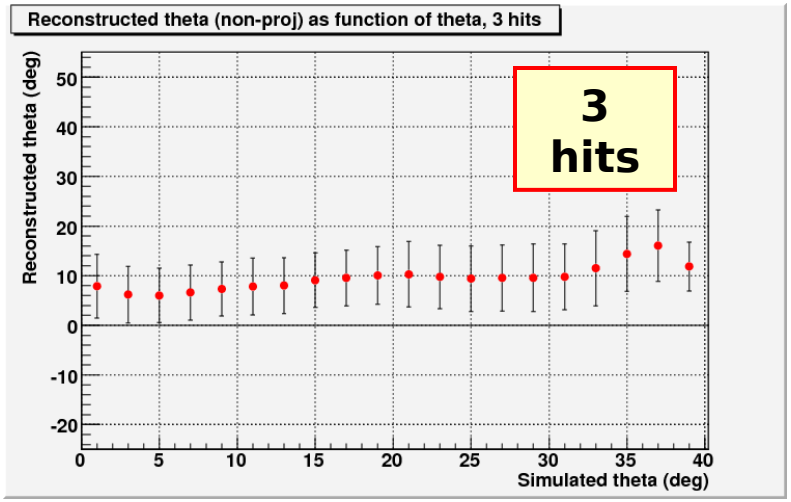
Standalone reconstruction: new results

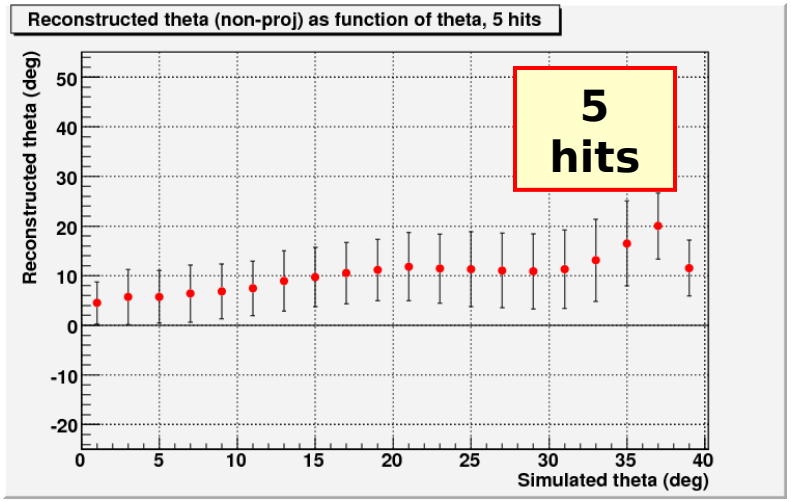
- Evolution of reconstructed θ (component along correct track only) for different numbers of hits shows degenerate region at 10º-30º:

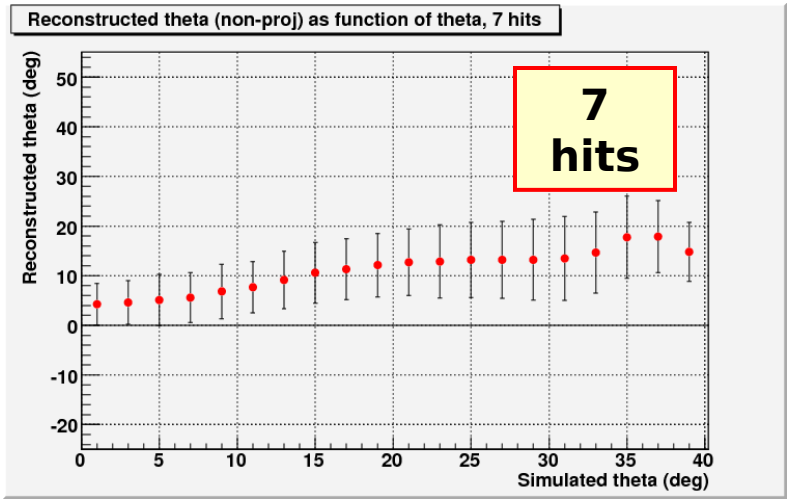


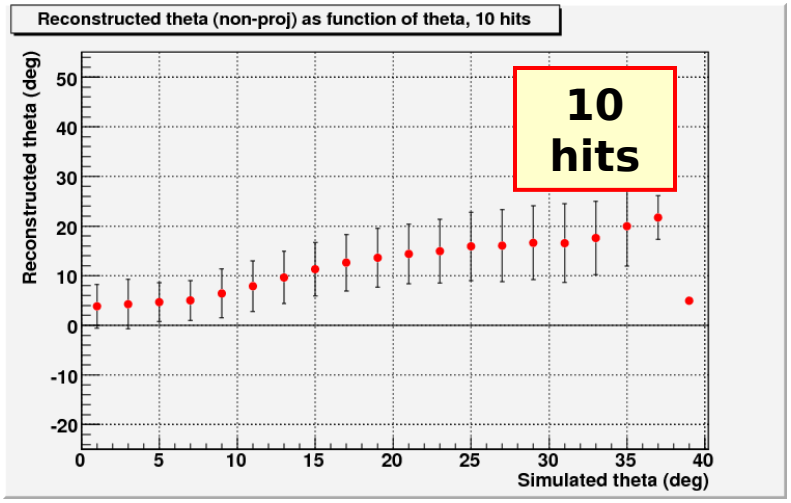
Standalone reconstruction: new results

- Evolution of reconstructed θ for different numbers of hits:





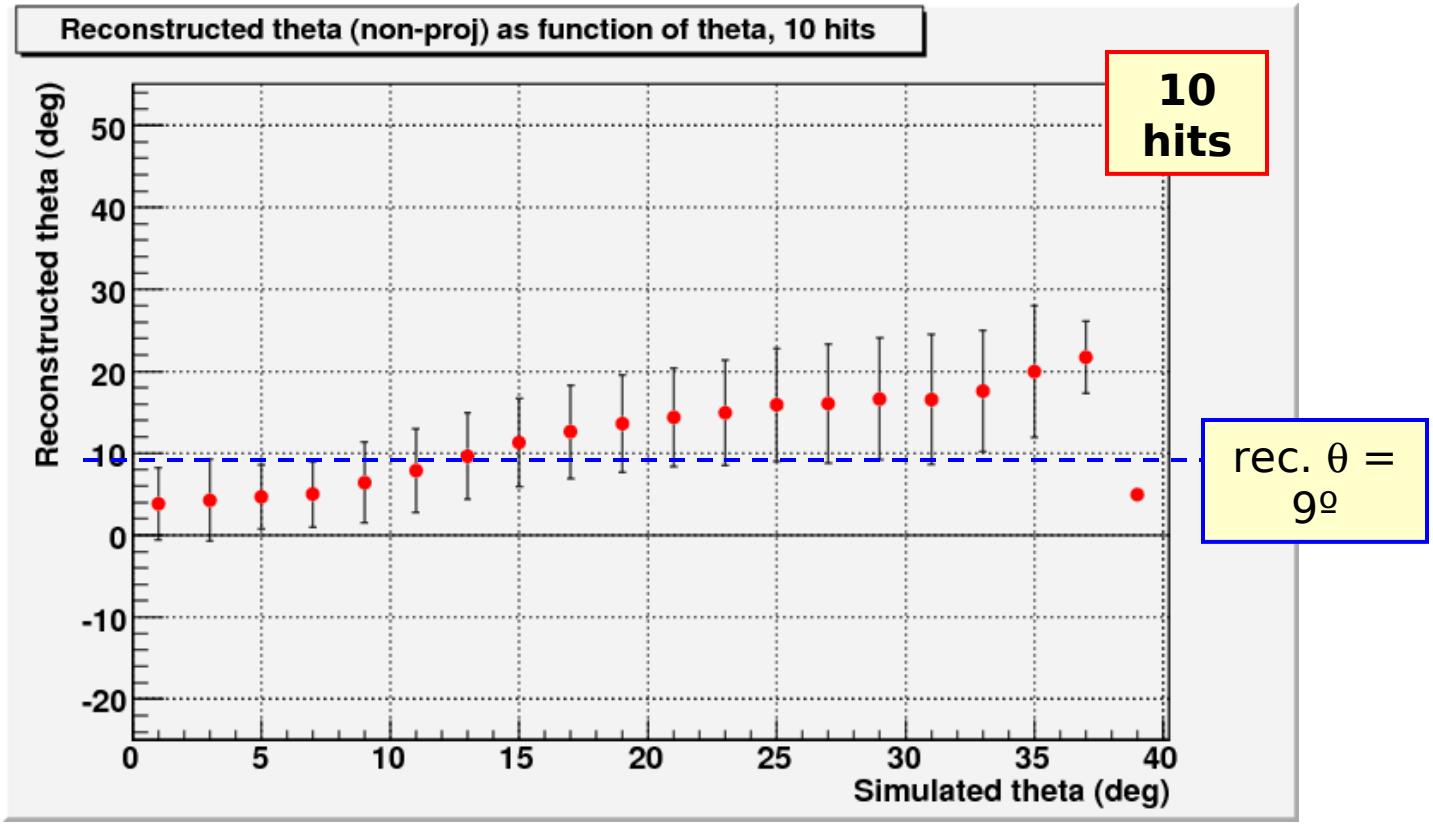




bars show RMS of distributions

Standalone reconstruction: new results

- Evolution of reconstructed θ with simulated θ is extremely slow
- Even for events with 10 hits, a reconstructed value θ ~ 8º-10º is within one standart deviation of the expected result for all angles in the 0º-30º range
- Reconstruction of θ appears not to be possible for Z = 1



bars show RMS of distributions

Track reconstruction using TOF

- TOF clusters may provide the hint that is needed for a reconstruction method without using the Tracker

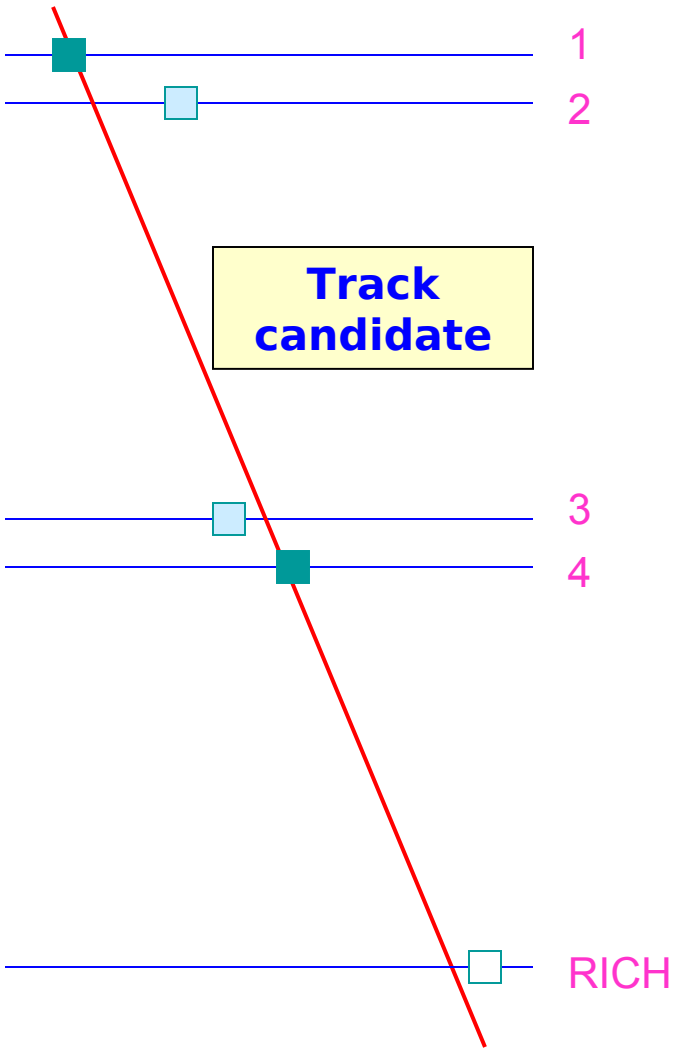
- TOF clusters used as reference points for track reconstruction

- Track assumed to be linear
  - linearity increases with particle energy

- Two reconstruction possibilities were considered:
  - TOF clusters only
  - TOF clusters + RICH particle signal

TOF track reconstruction

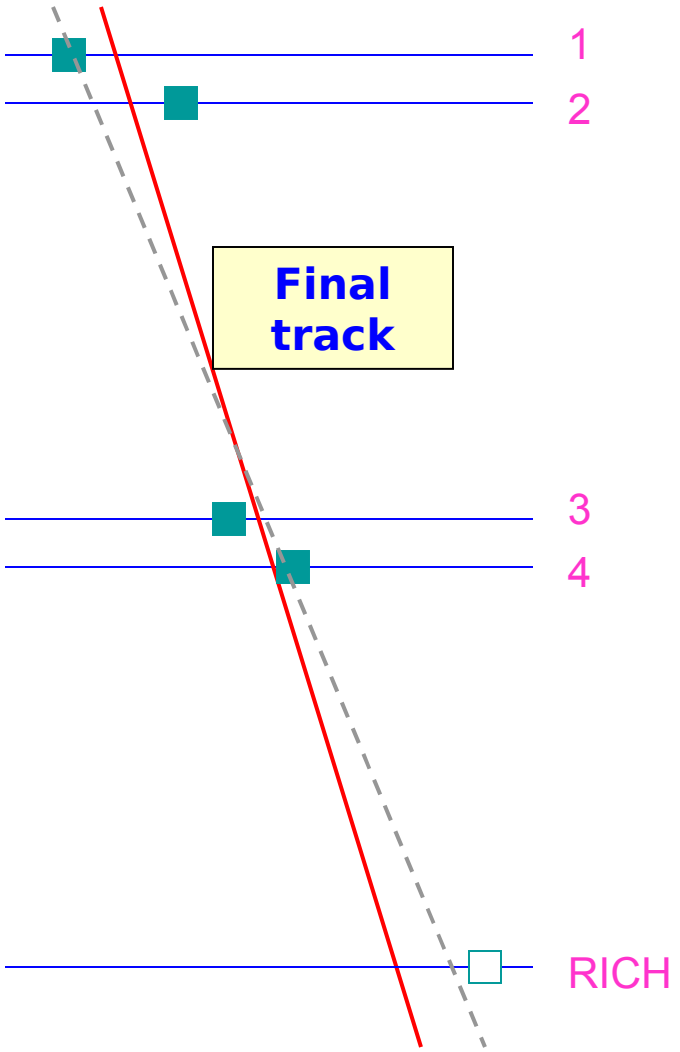
- Search for a TOF track:
  - All lines defined by pairs of clusters in planes 1, 4 are tested for nearby clusters in planes 2, 3 (cluster point < 5 cm from line as measured in the horizontal plane)
  - If at least one of the planes 2, 3 has a nearby cluster, the line is considered a TOF track candidate (3- or 4-plane)
  - Pairs of clusters in planes 2, 4 are tested to find possible track candidates where plane 1 has no cluster
  - RICH signal is ignored



TOF track reconstruction

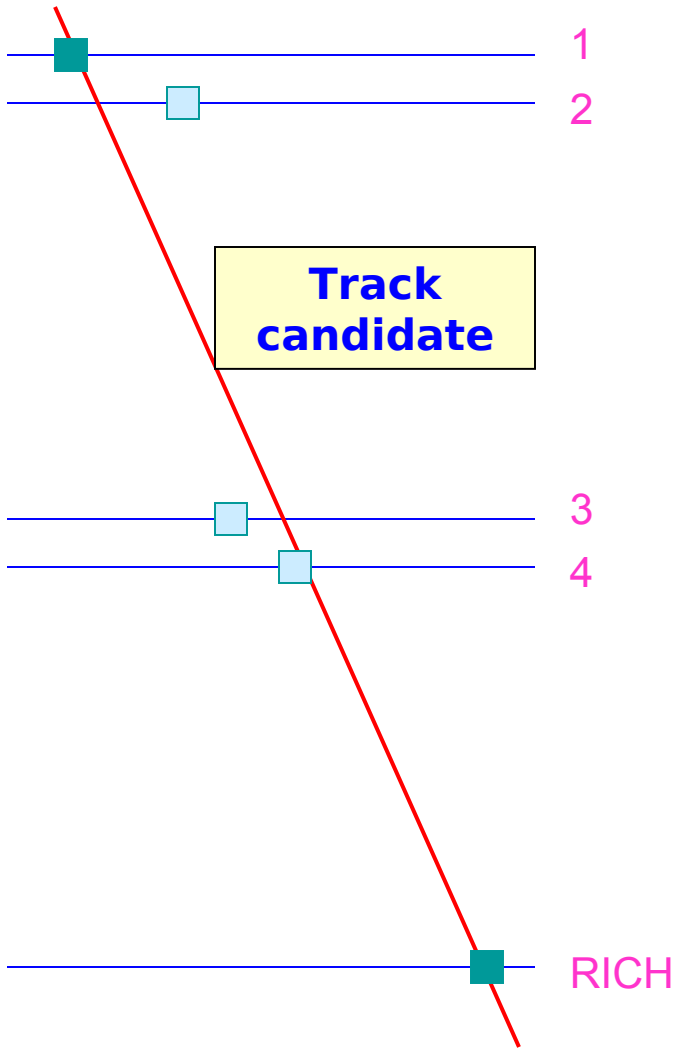
- TOF track candidate is accepted in one of two cases:
  - Exactly one 4-plane track candidate exists
  - Exactly one 3-plane track candidate exists and no 4-plane track candidate was found

- Final TOF track is obtained from x-z and y-z fits to the set of cluster points used, considering each plane's resolution in x and y



TOF+RICH track reconstruction

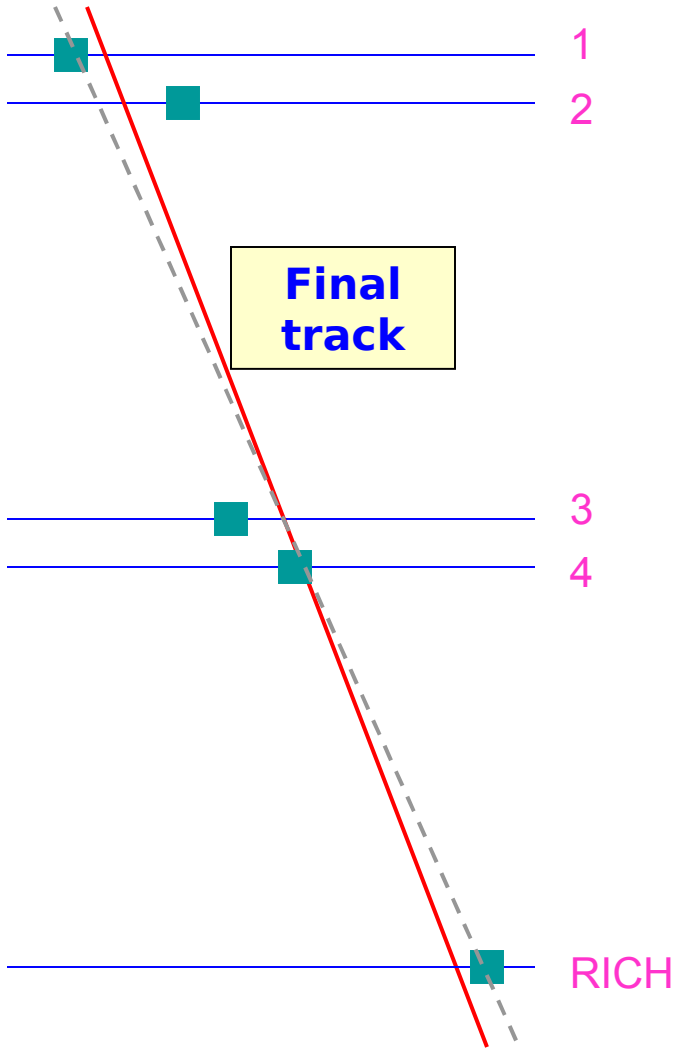
- Search for a TOF+RICH track:
  - Procedure similar to TOF-only case, but TOF plane 1 and RICH cluster (strongest hit) are now used as references
  - Lines connecting clusters in plane 1 with RICH cluster are tested for nearby clusters in planes 2, 3, 4 (cluster point < 5 cm from line as measured in the horizontal plane)
  - If at least two of the planes 2, 3, 4 has a nearby cluster, the line is considered a TOF-RICH track candidate (3- or 4-plane)
  - Lines connecting clusters in plane 2 with RICH cluster are tested to find possible track candidates where plane 1 has no cluster



TOF+RICH track reconstruction

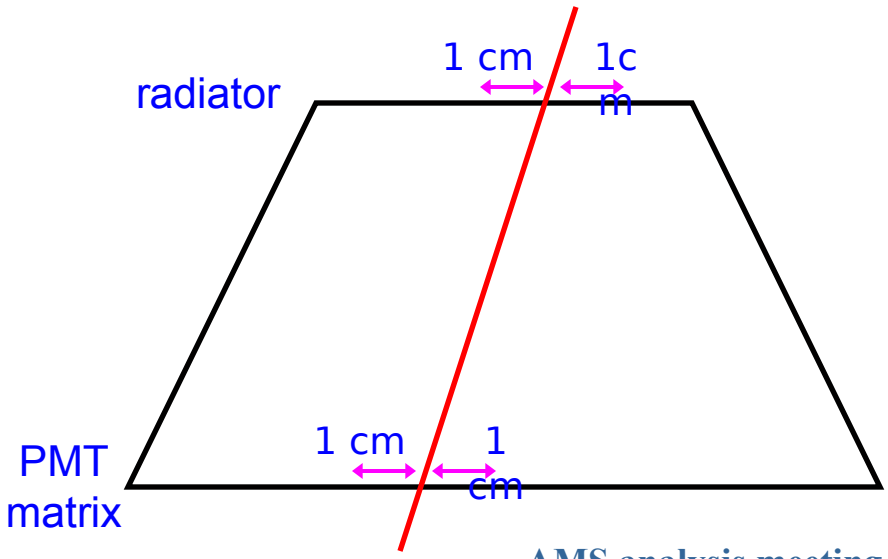
- TOF+RICH track candidate is accepted in one of two cases:
  - Exactly one 4-plane track candidate exists
  - Exactly one 3-plane track candidate exists and no 4-plane track candidate was found

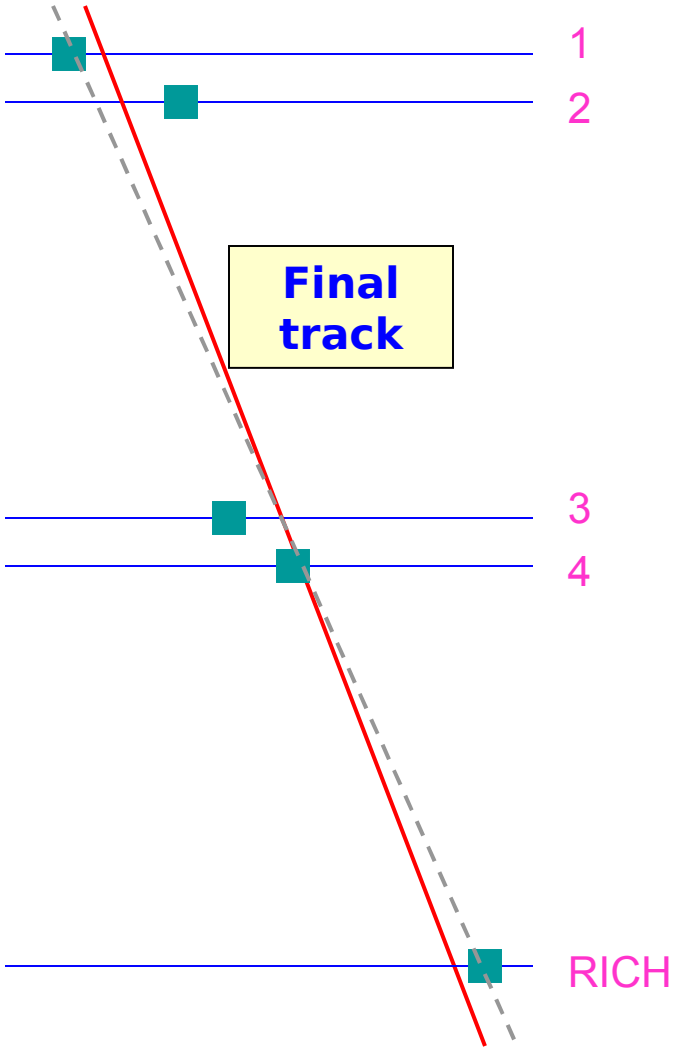
- Final TOF+RICH track is obtained from x-z and y-z fits to the set of cluster points used, considering each plane's resolution in x and y



TOF+RICH track reconstruction

- 5-parameter RICH reconstruction (standalone algorithm) applied to obtain θ_c
  - Final track used as hint for θ_c reconstruction
  - Track points at top and bottom of RICH allowed to change up to 1 cm from hint positions:





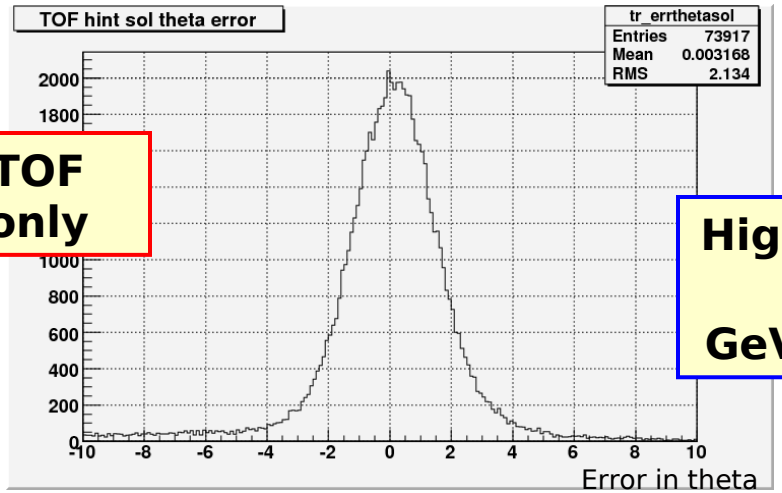
TOF & TOF+RICH rec: statistics

- Quality cuts applied for event selection:
  - TOF signal:
    - No more than 5 clusters in TOF
  - RICH hint:
    - Quotient between strongest and average PMT signal must be higher than 3 and lower than 10
    - Strongest PMT signal must be higher than 6 p.e.

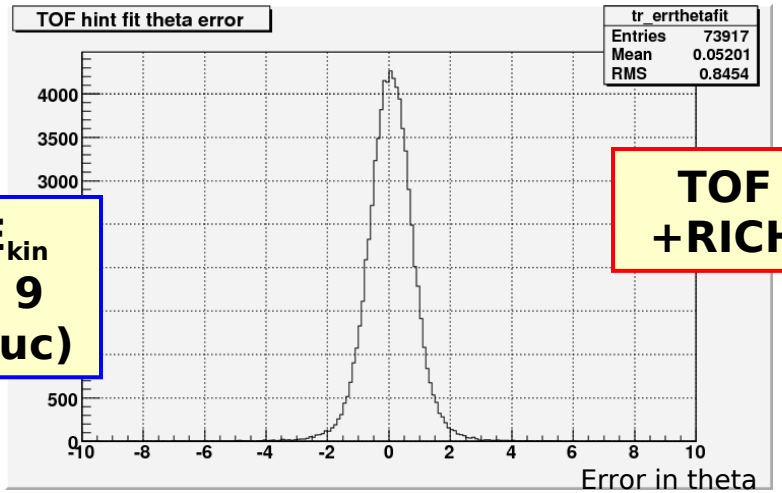
- For events having a RICH ring and $\beta \approx 1$ ($E_{kin} > 9$ GeV/nucleon), after applying cuts on TOF and RICH data:
  - 17.2% have a valid TOF reconstruction
  - 12.8% have a valid TOF+RICH reconstruction
  - 8.3% have valid TOF and TOF+RICH reconstructions (sample presented here)

TOF vs. TOF+RICH: θ comparison

- Reconstruction using TOF+RICH is much better than the one using TOF clusters only (2.13º vs. 0.85º for $\beta \approx 1$)

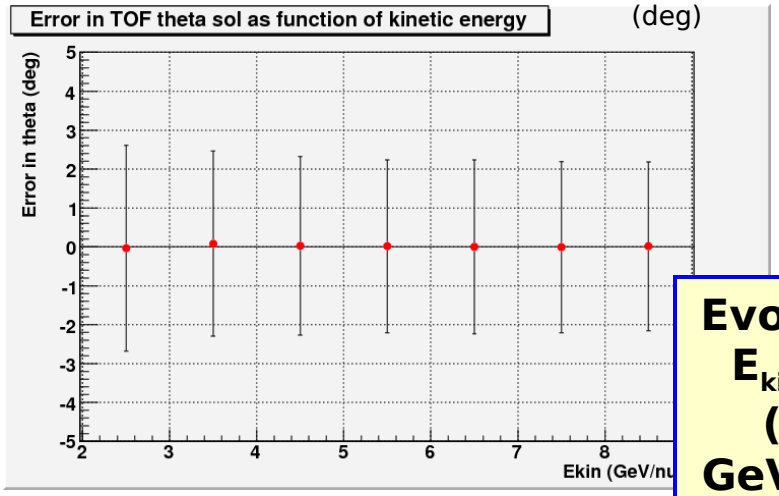


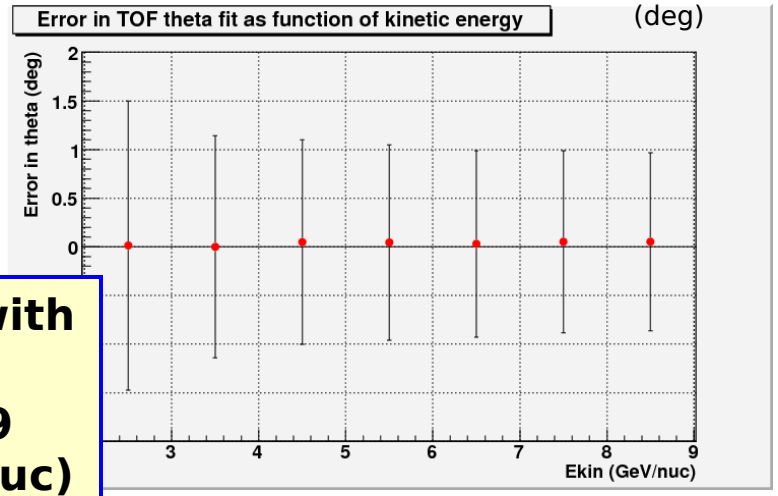
TOF only



TOF +RICH

High E_{kin} (> 9 GeV/nuc)



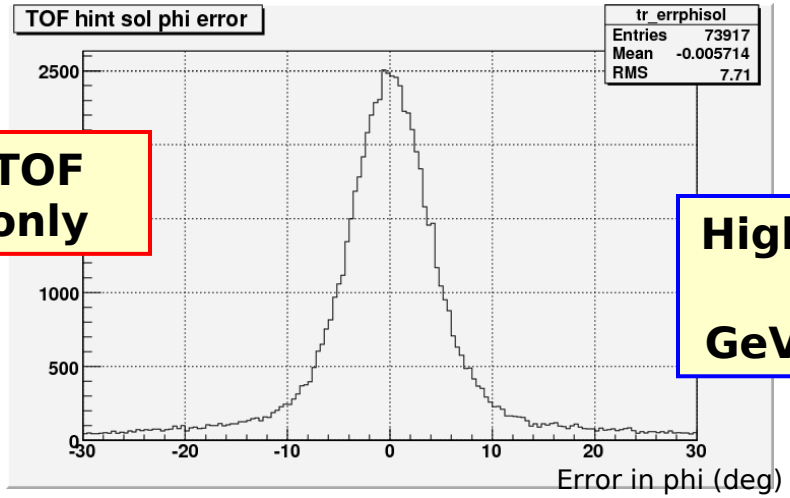


Evol with E_{kin} (2-9 GeV/nuc)

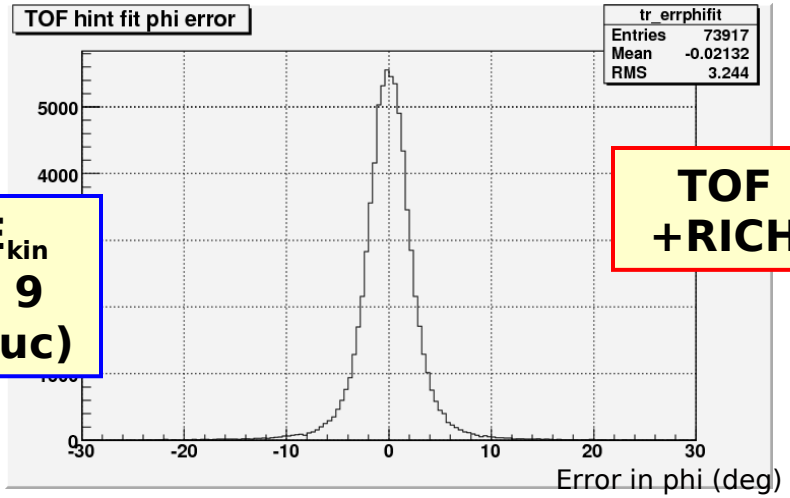
after quality cuts on TOF, RICH signals

TOF vs. TOF+RICH: ϕ comparison

- Reconstruction using TOF+RICH is much better than the one using TOF clusters only (7.71º vs. 3.24º for $\beta \approx 1$)

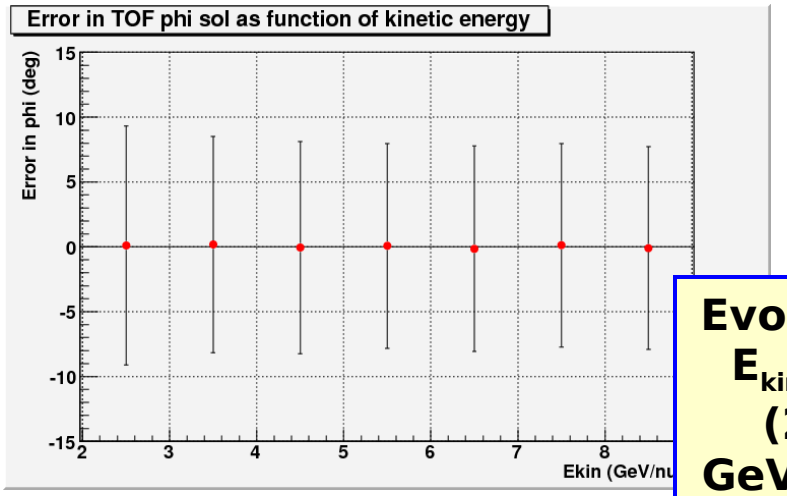


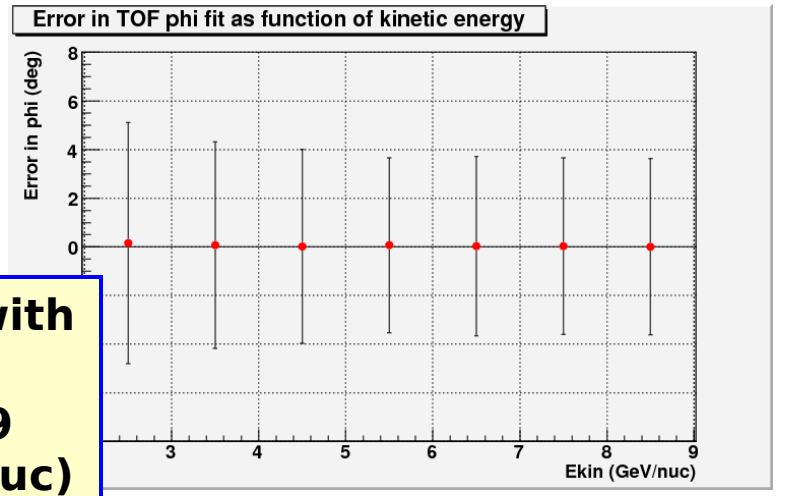
TOF only



TOF +RICH

High E_{kin} (> 9 GeV/nuc)



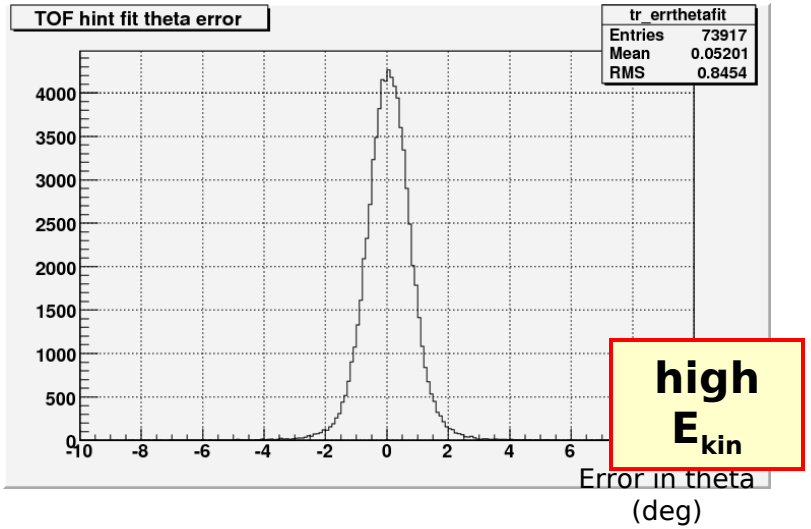


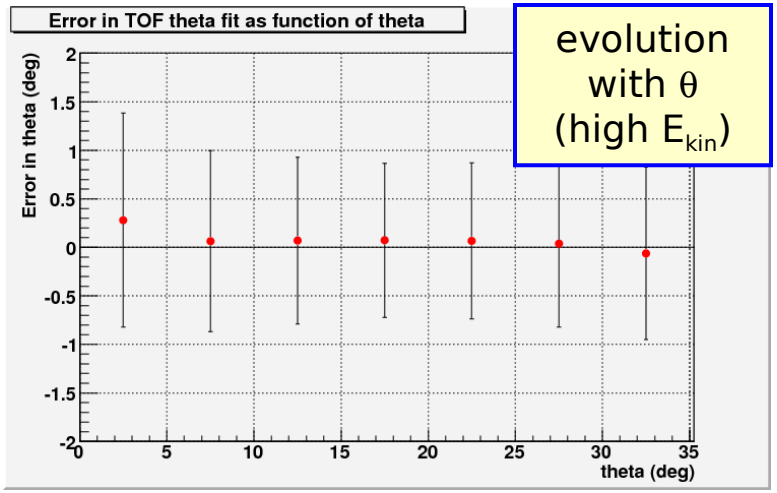
Evol with E_{kin} (2-9 GeV/nuc)

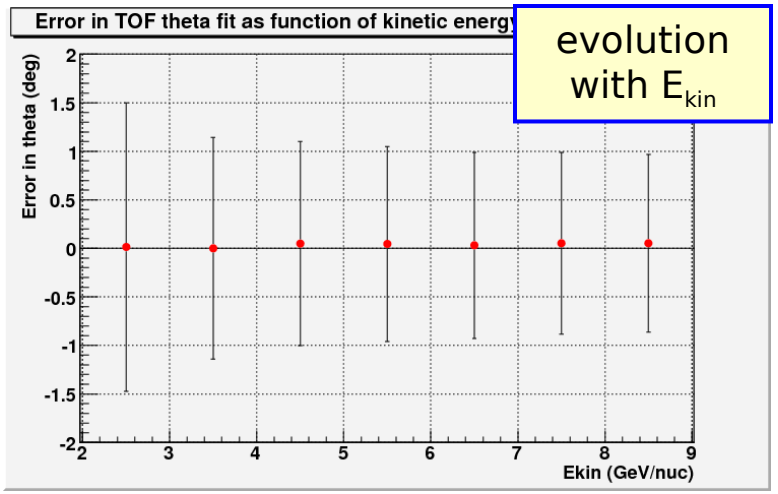
after quality cuts on TOF, RICH signals

TOF+RICH: θ reconstruction

- Results at high E_{kin} (>9 GeV/nuc):
  - No significant bias
  - σ_θ = 0.85°
- Larger uncertainty but no significant bias at lower energies
- Resolution in θ is almost independent of inclination



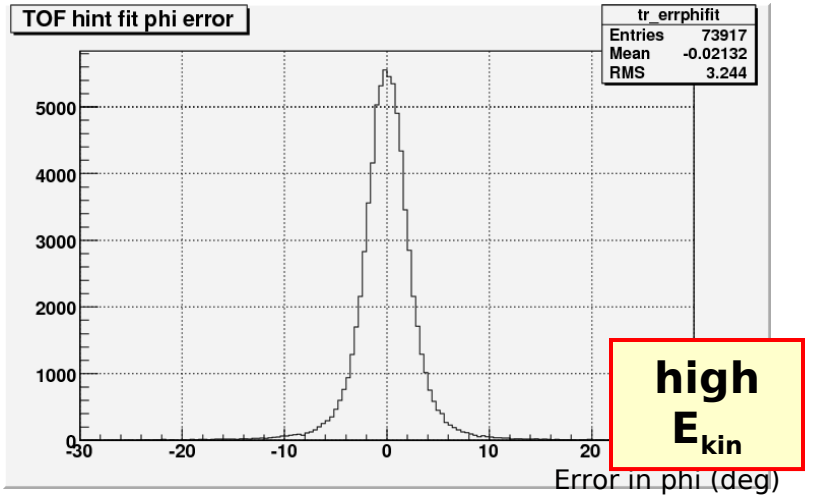


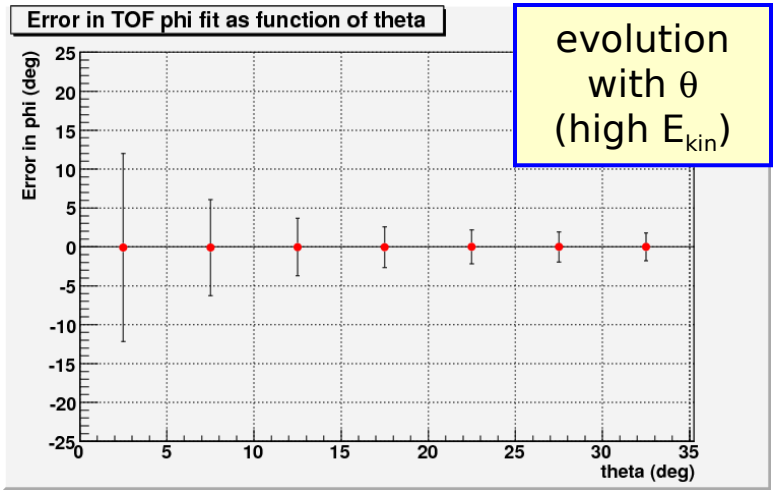


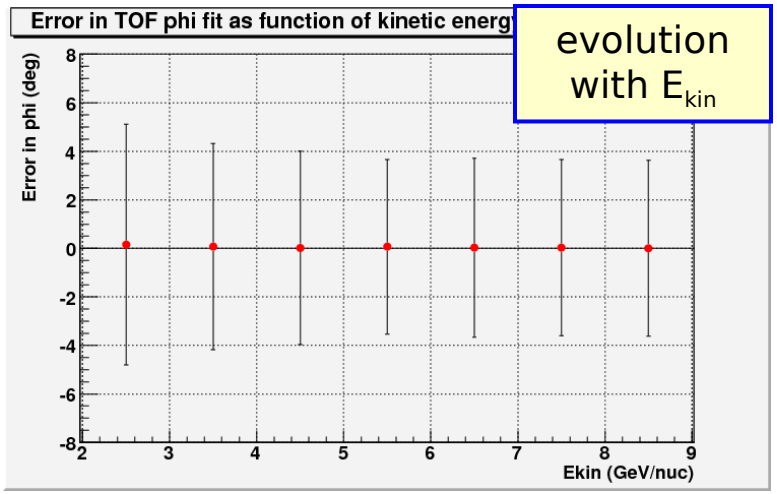
after quality cuts on TOF, RICH signals

TOF+RICH: ϕ reconstruction

- Results at high E_{kin} (>9 GeV/nuc):
  - No significant bias
  - σ_ϕ = 3.24°
- Larger uncertainty but no significant bias at lower energies
- Resolution in ϕ is depends strongly on inclination



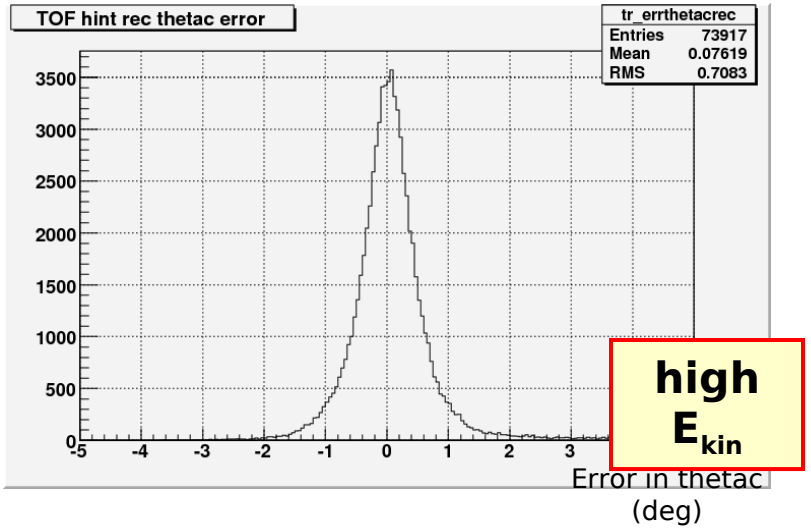


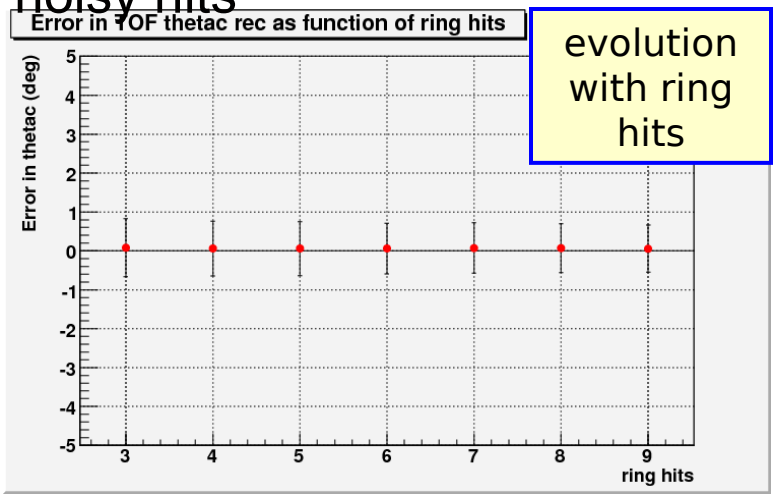


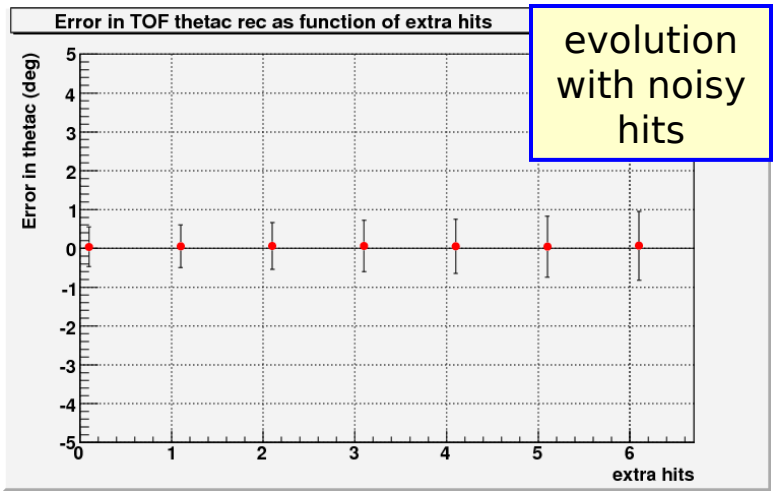
after quality cuts on TOF, RICH signals

TOF+RICH: θ_c reconstruction

- Results at high E_{kin} (>9 GeV/nuc):
  - No significant bias
  - $\sigma_{\theta c}$ = 0.71º = 12 mrad
    = 3 × Tracker resolution
- Resolution in θ_c is better for rings with more hits
- Reconstruction quality is lower for events with a high number of noisy hits



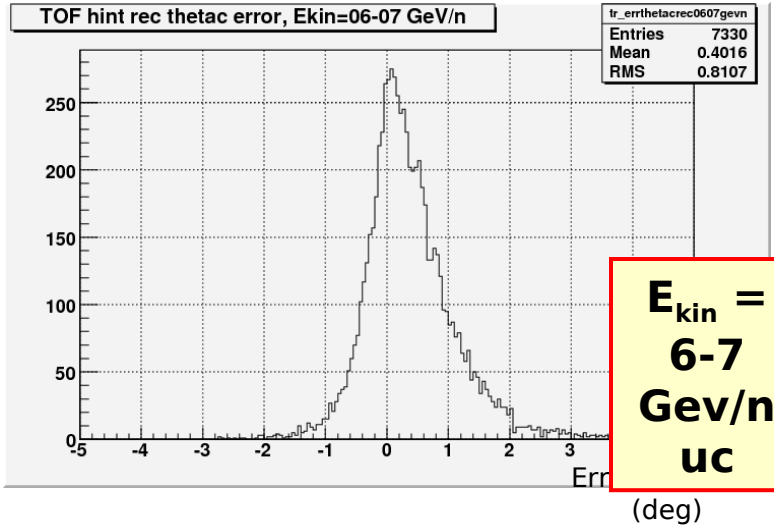


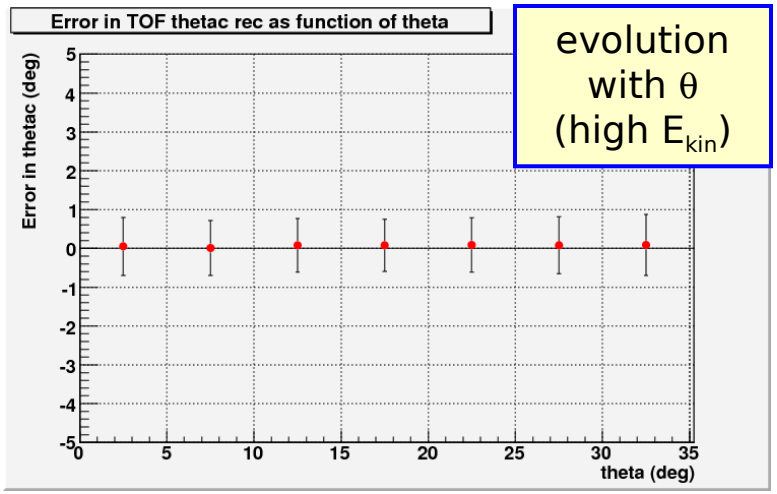


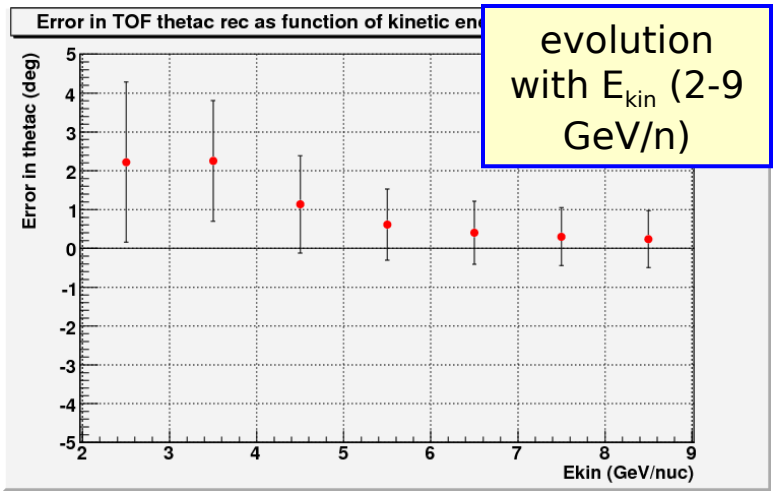
after quality cuts on TOF, RICH signals

TOF+RICH: θ_c reconstruction (cont'd)

- Bias towards larger θ_c becomes significant at lower energies (bias >0.5º below 6 GeV/nuc)
  - Average is shifted due to high angle tail
- Resolution in θ_c is almost independent of inclination





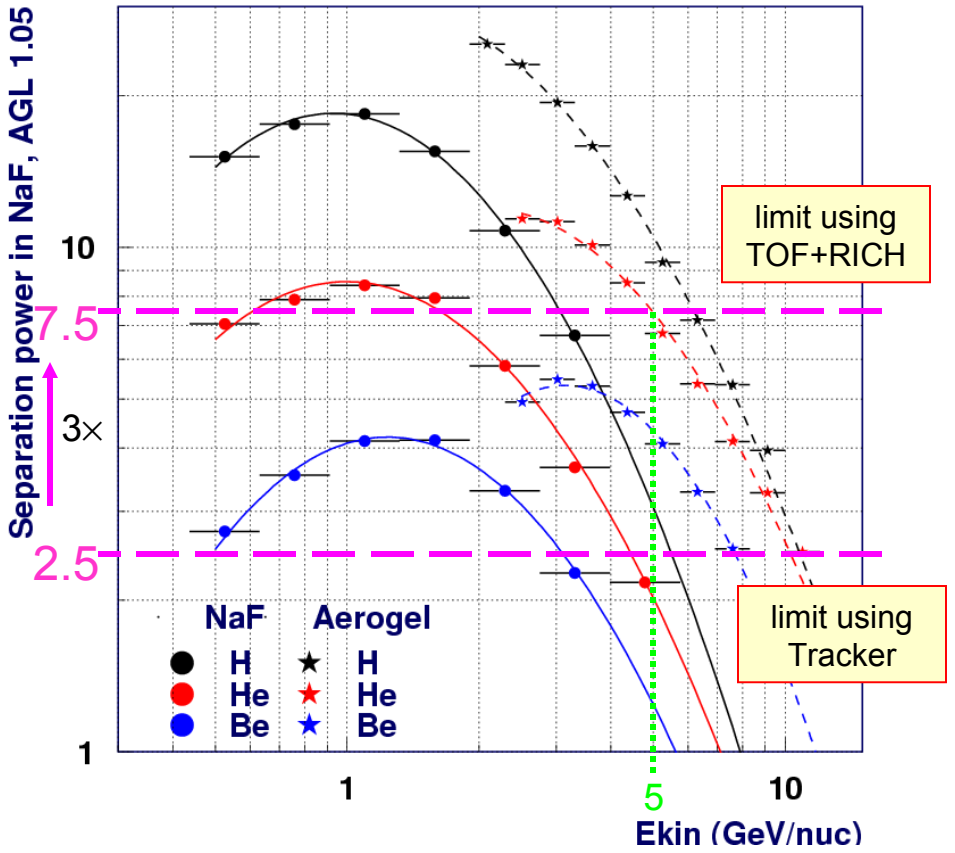


after quality cuts on TOF, RICH signals

Effect on separation power

- Mass resolution σ_m is directly proportional to $\sigma_{\theta c}$
- $\sigma_{\theta c}$ using TOF+RICH track being ~ 3 times worse implies reduction of separation power by a factor 3

- If mass separation is assumed to be possible where $\Delta m/\sigma_m > 2.5$, then using TOF+RICH track:
  - He separation will only be possible up to ~ 5 GeV/nuc
  - Be separation might not be possible



Separation power = $\Delta m/\sigma_m$ with Tracker

Conclusions

- Standalone reconstruction:
  - Reconstructed θ has a large bias towards lower values
  - Plateau region for intermediate θ, together with large fluctuations of reconstructed angle for events with similar inclinations, imply that this method of standalone reconstruction will not work for single-charged particles $\Rightarrow$ external track element is needed
- TOF-based reconstruction:
  - It is possible to obtain a reliable track from TOF or TOF+RICH cluster data for ~10% of events with a RICH ring
    - TOF reconstruction, 3 or 4 planes: $\sigma_\theta \sim 2^\circ$, $\sigma_\phi \sim 8^\circ$
  - Track quality improves significantly when RICH light guide signal is included
    - TOF+RICH reconstruction, 4 or 5 planes: $\sigma_\theta \sim 1^\circ$, $\sigma_\phi \sim 4^\circ$
  - No significant bias for θ and ϕ reconstructions even at lower E_{kin}
  - Track obtained from TOF+RICH may be used to obtain θ_c from constrained 5-parameter reconstruction
    - $\sigma_{\theta c} \sim 0.7^\circ = 12$ mrad at high E_{kin} ($3 \times$ Tracker uncertainty)
    - bias in θ_c becomes large at lower energies (< 6 GeV/nucleon)